

Expecting the Unexpected with the Fermi Gamma-ray Space Telescope

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Outline

- **Introduction - the Fermi Gamma-ray Space Telescope**
- **Characteristics that provide versatility**
 - **Instruments**
 - **Operations**
- **Time Domain Gamma-ray Astronomy**

The Fermi Gamma-ray Space Telescope

Prior to Fairing Installation



The Observatory



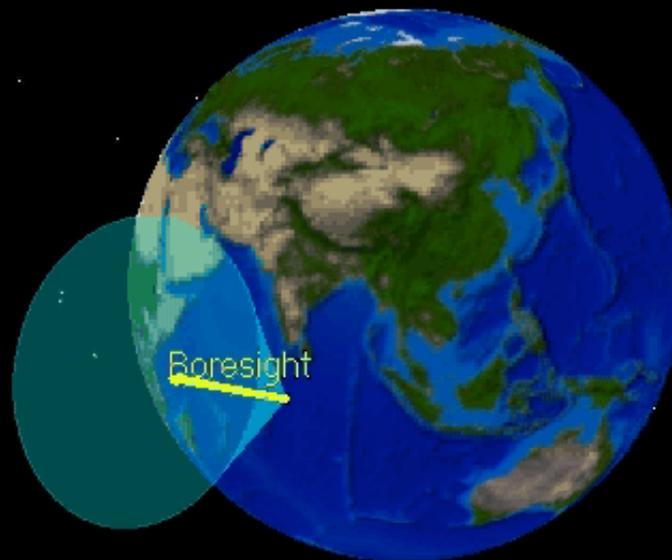
Large Area Telescope (LAT)
20 MeV - >300 GeV

Gamma-ray Burst Monitor (GBM)
NaI and BGO Detectors
8 keV - 40 MeV

KEY FEATURES

- **Huge field of view**
 - LAT: 2.4 sr; 20% of the sky at any instant;
 - GBM: whole unocculted sky at any time.
- **Broad energy range.**
 - Total of >7 energy decades!
- **Every photon can be time-tagged.**
 - 1 microsecond accuracy

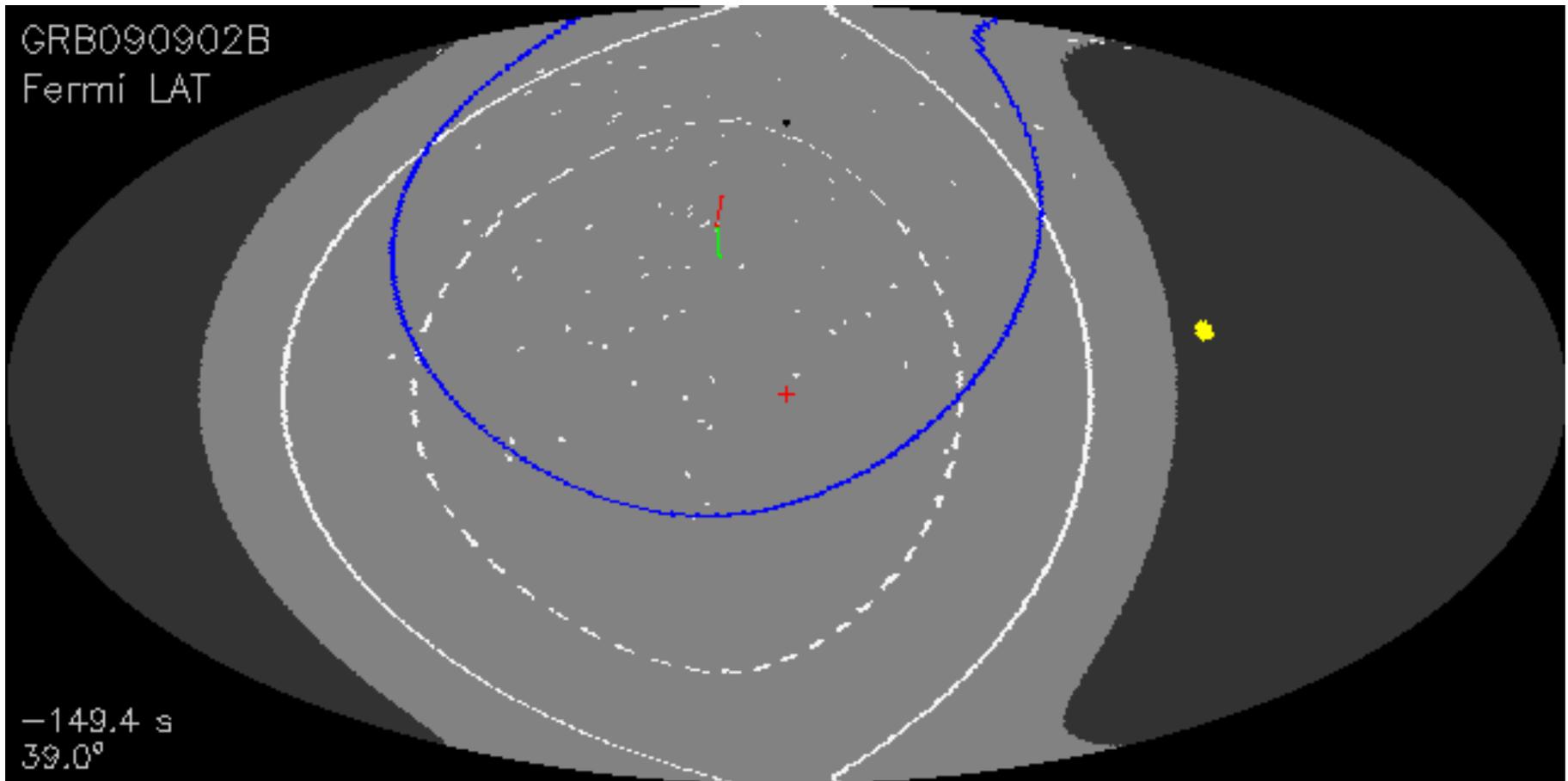
Survey Mode - Default



- **Rock north for one orbit and south for the next.**
- **Keep LAT Field of View away from the bright Earth limb**
- **Covers the full sky every 3 hours.**

GRB090902B - Autonomous repoint

- LAT pointing in celestial coordinates from -120 s to 2000 s
 - Red cross = GRB 090902B
 - Dark region = occulted by Earth; Yellow disk = Sun
 - Blue line = LAT FoV
 - White lines = 20° (Earth avoidance angle) / 50° above horizon
 - White points = LAT events



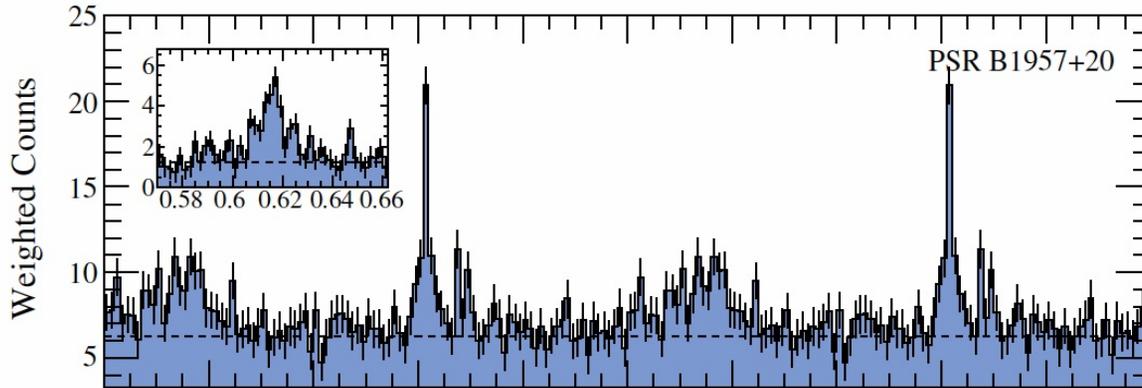
Other Fermi Pointing Modes

- 1. Target of Opportunity - On short notice, the observatory can be pointed at any direction in the sky. In this mode, many parts of the sky receive no coverage.**
- 2. Planned Pointing - With advance planning, some survey mode observations can be done during times when the target is occulted.**

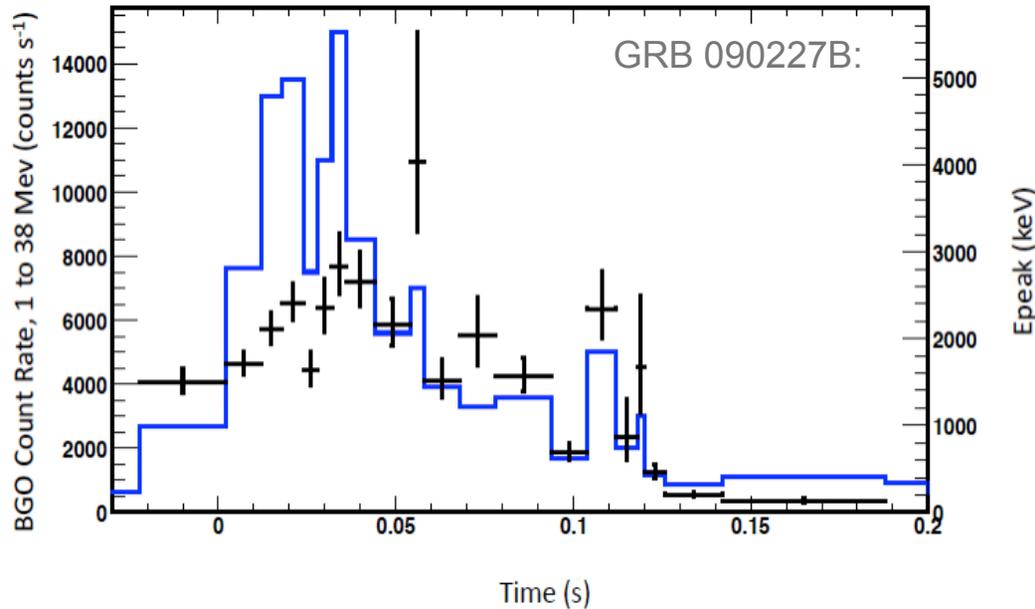
Time Domain Gamma-ray Astronomy with Fermi

Because all the Fermi gamma-ray data are made public immediately, these sample results come from independent investigations, cooperative efforts, or the instrument teams.

Variability on Very Short Time Scales



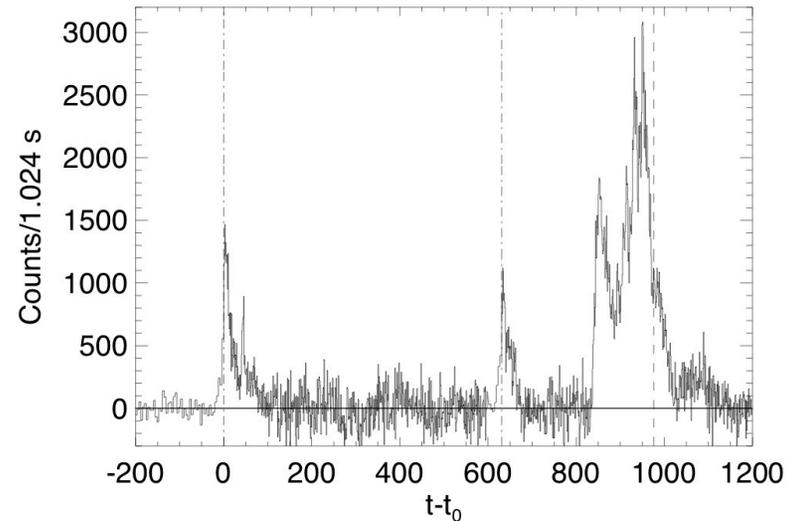
FWHM of the sharp peak of this ms pulsar is 23 ± 11 microseconds.
Guillemot et al. 2012



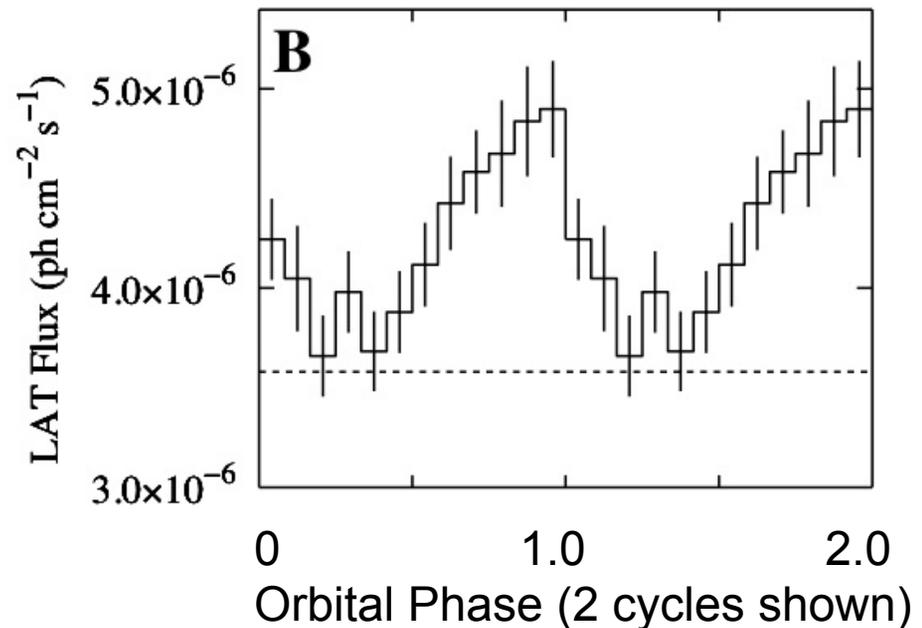
GBM measured both flux and spectral variation for this Gamma-Ray Burst on a time scale of 10 milliseconds.
Guiriec et al. 2010

Variability on Short Time Scales

GRB 091024 showed emission extending for **minutes**. Gruber et al. 2011

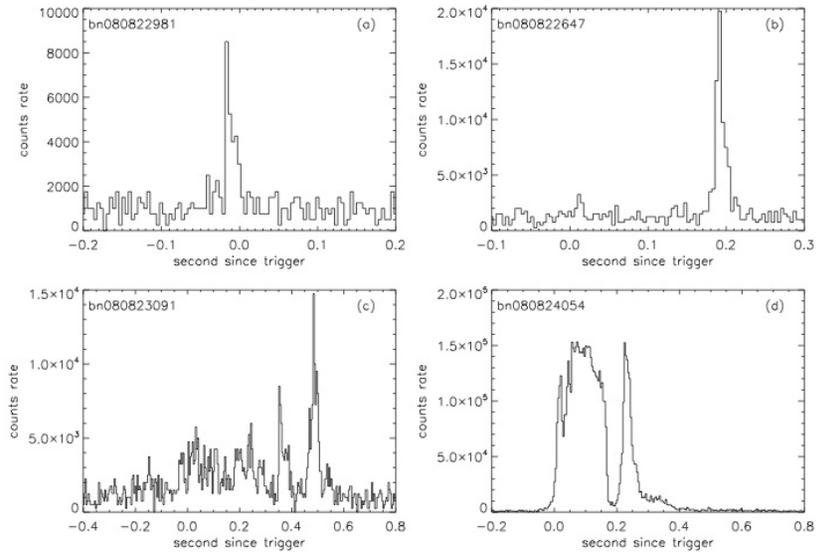


When in an active gamma-ray state, the microquasar system Cygnus X-3 shows variability with a period of **4.8 hours**. Abdo et al. 2009

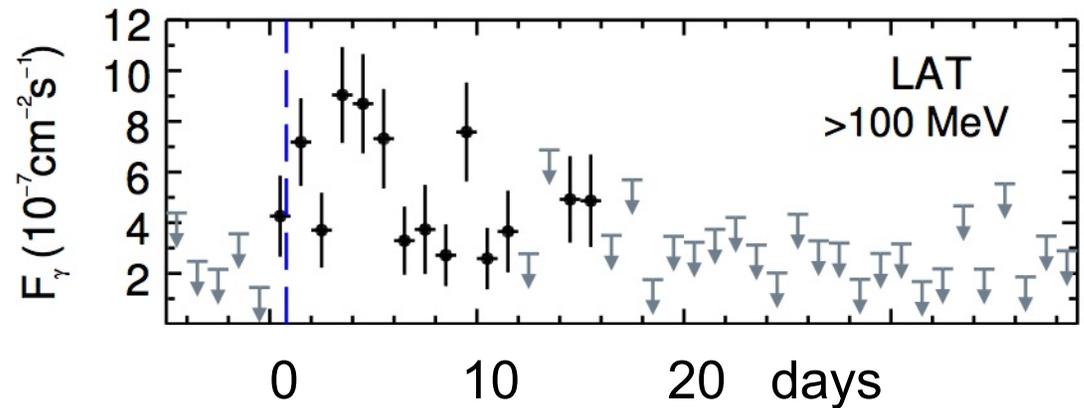


Variability on Intermediate Time Scales

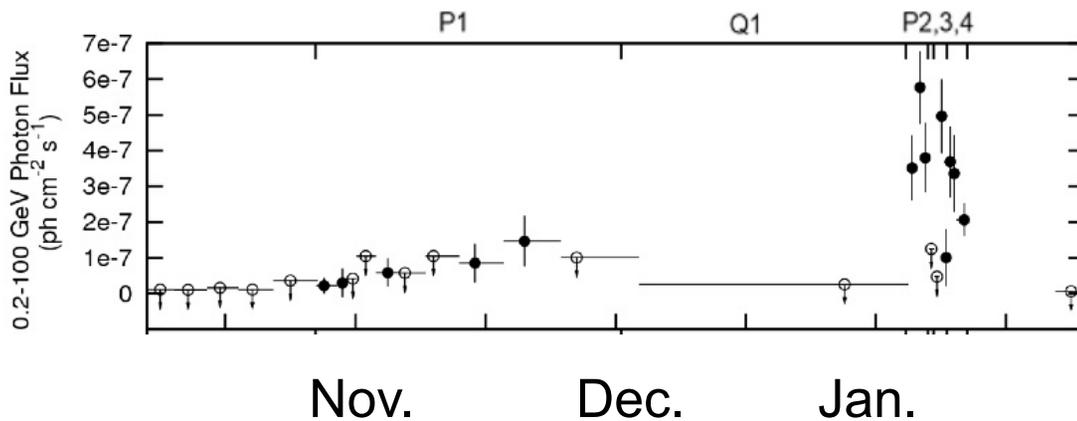
**Soft Gamma Repeater
J0501+4516 produced 29
bursts in an episode
lasting 13 **days**. Lin et al.
2011**



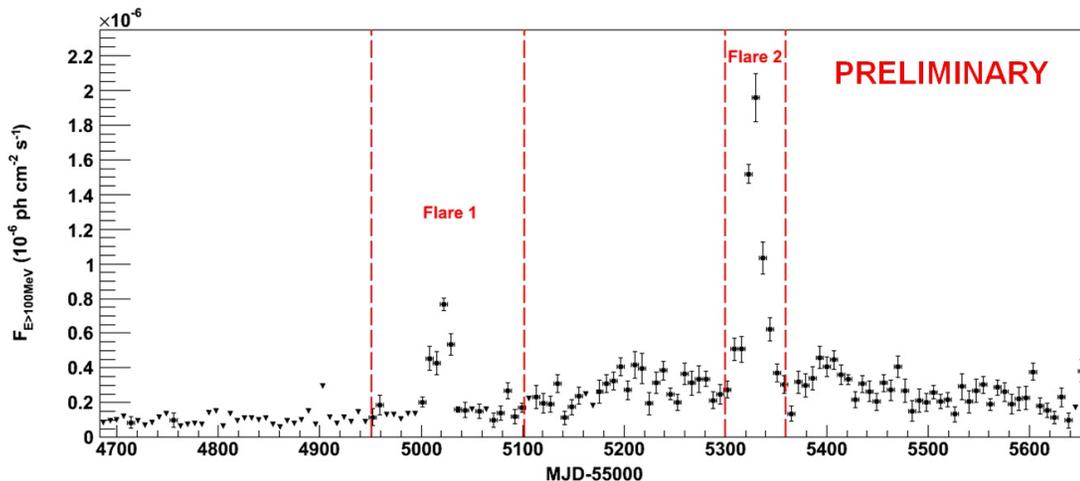
**The symbiotic binary
system V407 Cyg
gamma-ray outburst
extended for 2 **weeks**.
Abdo et al. 2010**



Variability on Longer Time Scales



The PSR B1259-63 binary system showed activity around the 2010 periastron lasting for **months**. Tam et al. 2011



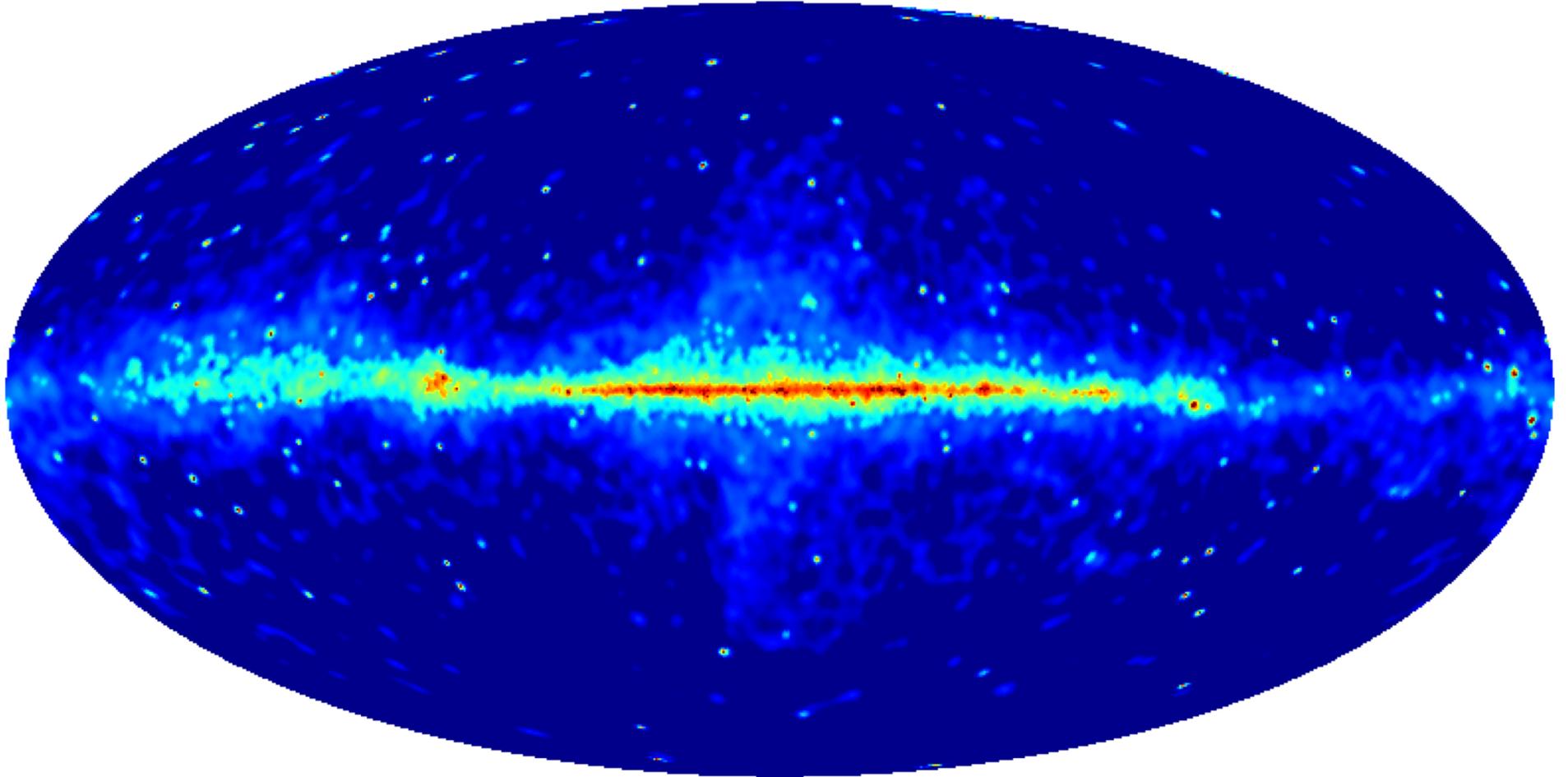
AGN PKS 1424-418 had two bright flares in 2 1/2 **years**. Longo et al. 2011

Time scales beyond what Fermi can measure

**For steady sources, longer exposures
produce more detailed (and sometimes
unexpected) results**

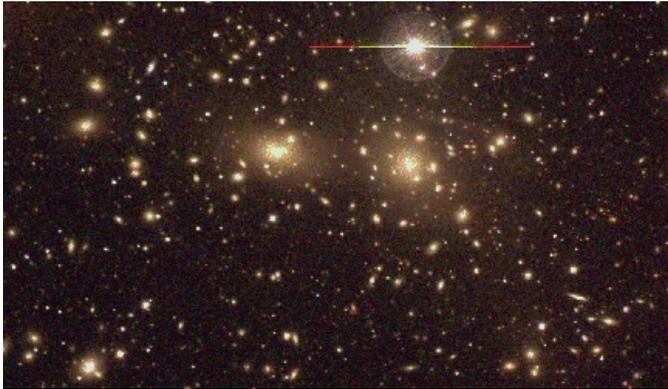
The Gamma-ray Sky above 10 GeV

Adaptively smoothed image courtesy of the LAT collaboration



In addition to nearly 500 sources at these energies (see poster 149.20), the sky shows large-scale features like the previously reported “Fermi bubbles” (Su, Slatyer, Finkbeiner, 2010)

What is Not Seen Can Also Be Important



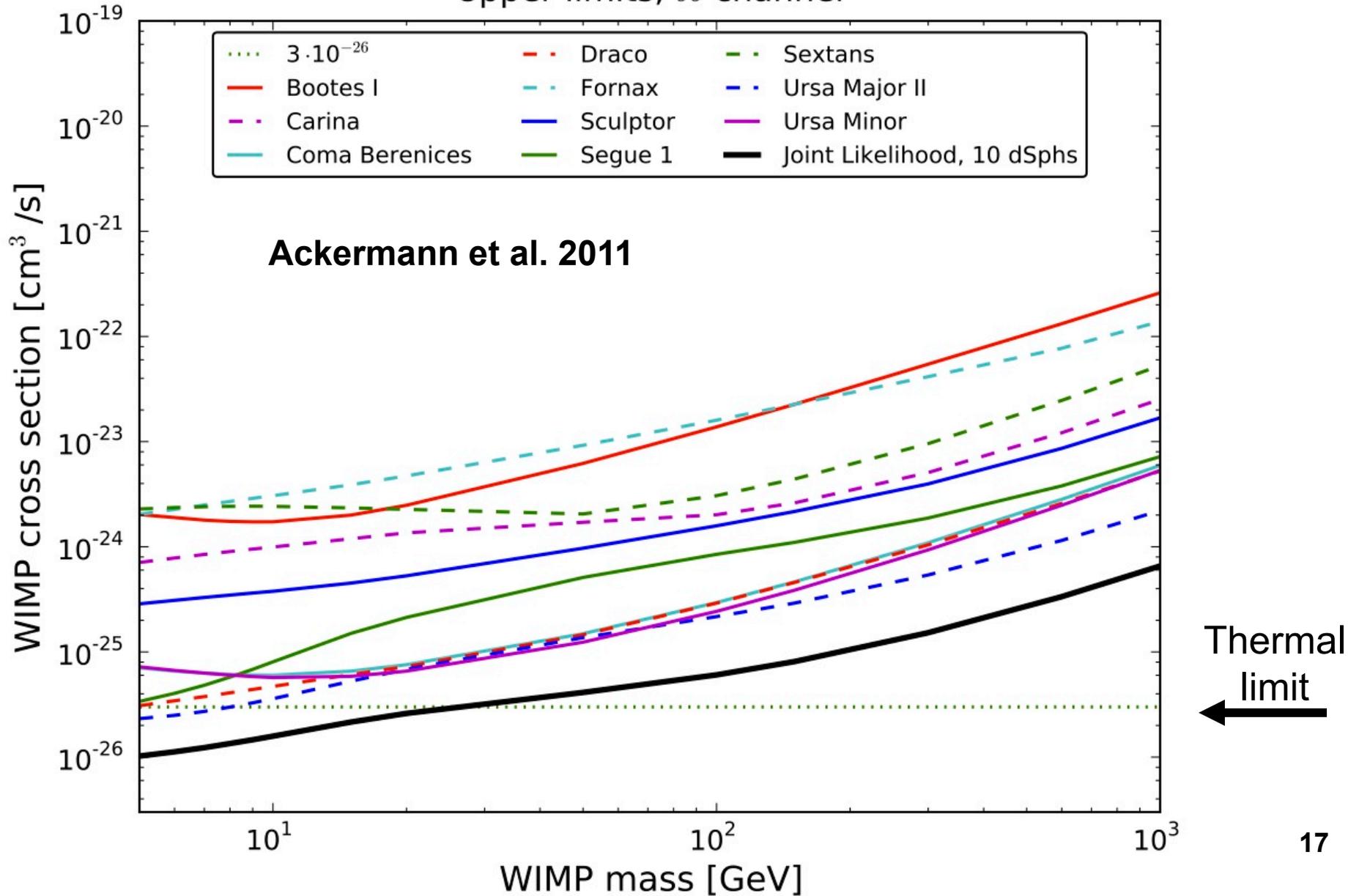
Some clusters of galaxies were predicted to be gamma-ray sources. None are seen in the Second LAT Catalog, indicating that the predictions were too optimistic.



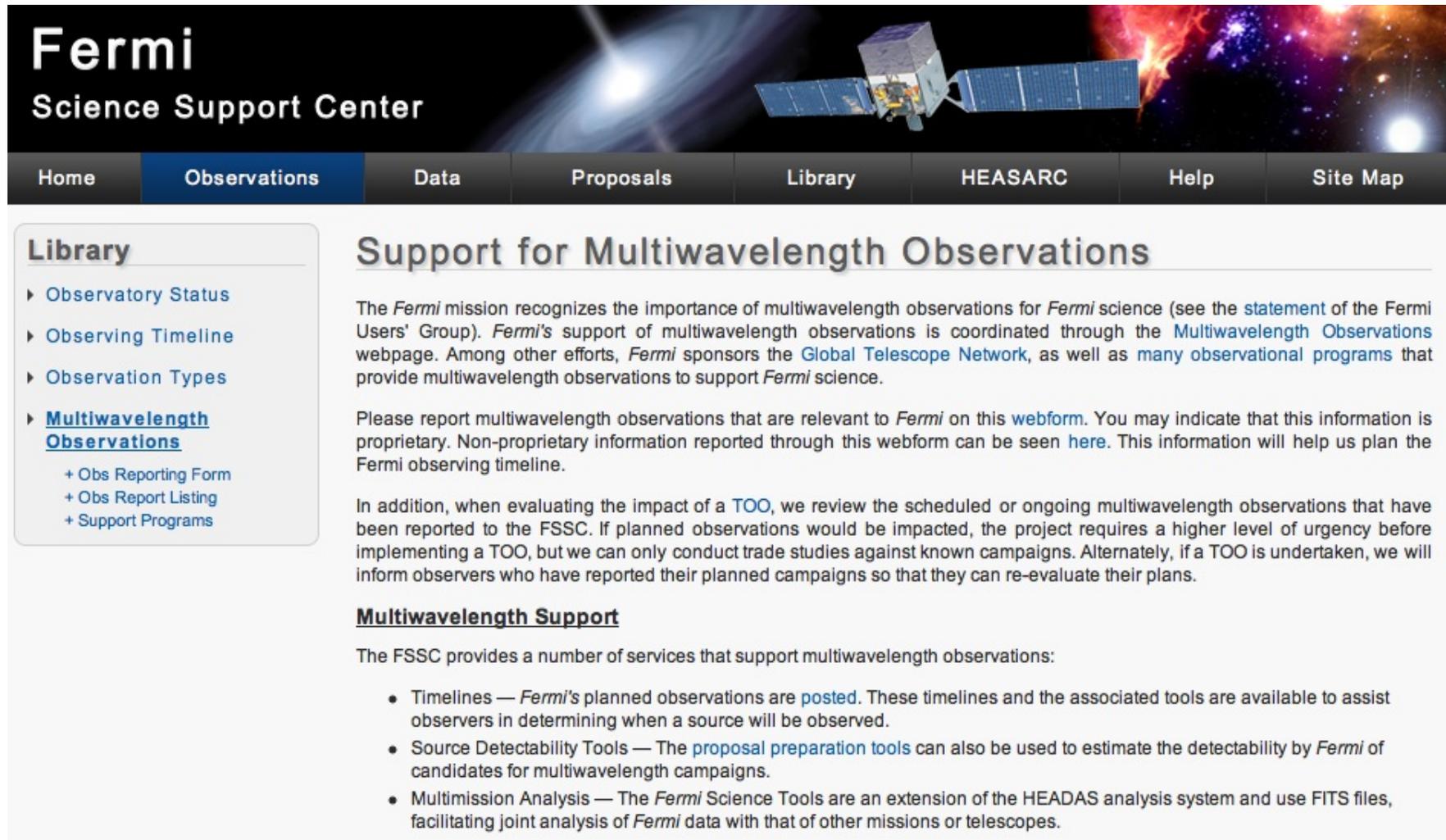
Dwarf spheroidal galaxies are thought to be largely composed of dark matter. If dark matter consists of some types of Weakly Interacting Massive Particles (WIMPs), such galaxies would be gamma-ray sources visible to Fermi LAT. Their absence puts constraints on dark matter models.

Fermi LAT Constraints on Dark Matter

Upper limits, $b\bar{b}$ channel



From Observations to Understanding - I



Fermi
Science Support Center

Home Observations Data Proposals Library HEASARC Help Site Map

Library

- ▶ [Observatory Status](#)
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- ▶ [Observation Types](#)
- ▶ [Multiwavelength Observations](#)
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Support for Multiwavelength Observations

The *Fermi* mission recognizes the importance of multiwavelength observations for *Fermi* science (see the [statement](#) of the Fermi Users' Group). *Fermi*'s support of multiwavelength observations is coordinated through the [Multiwavelength Observations](#) webpage. Among other efforts, *Fermi* sponsors the [Global Telescope Network](#), as well as [many observational programs](#) that provide multiwavelength observations to support *Fermi* science.

Please report multiwavelength observations that are relevant to *Fermi* on this [webform](#). You may indicate that this information is proprietary. Non-proprietary information reported through this webform can be seen [here](#). This information will help us plan the *Fermi* observing timeline.

In addition, when evaluating the impact of a [TOO](#), we review the scheduled or ongoing multiwavelength observations that have been reported to the FSSC. If planned observations would be impacted, the project requires a higher level of urgency before implementing a TOO, but we can only conduct trade studies against known campaigns. Alternately, if a TOO is undertaken, we will inform observers who have reported their planned campaigns so that they can re-evaluate their plans.

Multiwavelength Support

The FSSC provides a number of services that support multiwavelength observations:

- Timelines — *Fermi*'s planned observations are [posted](#). These timelines and the associated tools are available to assist observers in determining when a source will be observed.
- Source Detectability Tools — The [proposal preparation tools](#) can also be used to estimate the detectability by *Fermi* of candidates for multiwavelength campaigns.
- Multimission Analysis — The *Fermi* Science Tools are an extension of the HEADAS analysis system and use FITS files, facilitating joint analysis of *Fermi* data with that of other missions or telescopes.

<http://fermi.gsfc.nasa.gov/ssc/observations/multi/>

From Observations to Understanding - II

Fermi Guest Investigator Program

The Fermi Cycle-5 amendment to the 2011 ROSES NRA was released on October 31, 2011. Proposals to participate in the Cycle-5 program are due on **January 20, 2012**.

Fermi PIs can propose to:

- Analyze GBM or LAT event data from the beginning of science operations
- Analyze higher level data released by the LAT: lightcurves of bright or transient sources; and a point source catalog.
- Carry out pointed LAT observations. However, proposers should be aware that very strong science justifications will be required in view of the probable low additional scientific benefit of such observations see the Fermi Users' Group (FUG) analysis at http://fermi.gsfc.nasa.gov/ssc/proposals/pointing_analysis/. Pointed observations will follow the same open data policy as sky survey data, i.e., they will become public immediately.
- Support **correlated observations of gamma-ray sources** at other wavelengths that are directly relevant to Fermi.
- Perform theoretical studies of gamma-ray sources.
- Obtain observing time on the NRAO and NOAO facilities or on the Suzaku satellite in support of Fermi-related science.

<http://fermi.gsfc.nasa.gov/ssc/proposals/>

Summary - Expecting the Unexpected

The flexibility and versatility of the Fermi instruments and operations have produced a wide range of results, including time domain studies on many time scales and continual improvements in both exposure depth and energy range for steady sources.

Multiwavelength and theoretical studies are essential to make the best scientific use of the Fermi observations. The Guest Investigator program supports such work.

The Fermi Web site is <http://www.nasa.gov/fermi>

All the Fermi gamma-ray data are public immediately.
Join the fun!